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ARCTIC TECHNOLOGY: Part I Canada: nature's riches from man-made islands
Part II Norway: ice, vessels and structure studies
Part III How geotechnical engineers conquered the Beaufort Sea

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Started also last year were: Koakloak 0-22 where logging shows signs of oil and gas as the 16 000ft target depths (drilling last year reached 12 200ft); and Orvilruk 0-3 which fell short of its [illegible] td by just under 4 000ft but no logging was carried out.

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The company plans to complete these wells early in the season to allow production testing and analysis before the ice closes in once again.

Some 50km southeast of Kopanoar lies the Imperial Oil Issungnak discovery which flowed 2 400bbl/d early last year. This is in the relatively shallow waters of the McKenzie Delta and lies just north of the Isserk gas discovery made in 1978. The well was drilled from one of the 15 artificial islands in the area.

With the Kopanoar and Issungnak finds now identified, hopes for the Beaufort Sea as an oil producing area are being raised. Some experts believe that the area has the potential for 30-40Bbbl. Dome has already identified some 45 structures and believes there are at least 100 worth investigation — Kopanoar alone is said to hold a potential 1Bbbl.

Arctic islands

Further north in the Arctic islands, gas is the main commodity with some 16Tft³ already identified offshore and another 6-7Tft³ onshore. Oil is being found however. Panarctic Oils announced a significant discovery in 348m of water some 18 miles northeast of Lougheed island. Drilled from an ice island, the well, Skate B-80, tested 775bbl/d of 33°API crude and 5.7MMft³/d of gas even though the td of 2000m had only reached halfway. Estimates from company spokesmen suggested that the reservoir held some 300MMbbl. Hydrocarbons were also traced in two other wells off the island — Cisco B-66 and MacLean I-77 — and testing is likely soon.

Plans to bring in much of the gas found in the Arctic Islands area are progressing and it is now probable that the 'Arctic Pilot Project' will go ahead. [illegible] by specially built ice breaking LNG carriers from production facilities barge mounted at Melville Island where the Drake Point gas field is located. APP has signed [illegible] Texas Eastern, [illegible] Natural Gas and Columbia Gas Systems for the delivery of 450MMft³/d, half of which will be offset by supplies from Western Canada along the TransCanada Pipeline to the Toronto area and from there down into the US.

This project could start in 1985 with the West Canada supplies beginning in 1983. The term is for 20 years.

Given the high cost of operating in the Arctic area this is seen as a suitable first step to produce revenue and will cost in the region of $2 000 million.

A more sophisticated and costly plan exists to run a pipeline to eastern markets. Upwards of $13 000 million are involved in the 'Polar Gas Project', a Y-shaped line that would take gas from the High Arctic and McKenzie Delta to the main consuming parts of Canada. Backing the project are Petrocanada, the state oil concern, which is also very much behind the LNG tanker deal, Panarctic, TransCanada which is 47 per cent owned by Dome, Tenneco and the Ontario Energy Corporation.

The drift away from the Arctic area because of the seemingly better prospects off the East Coast and in the other main prospecting areas in the south of the country could, some believe, scuttle such an ambitious project. □

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In the oil and gas rich theatre of the Canadian North, on which the limelight of Arctic technology remains firmly fixed, aggressive and innovative operators are moulding the hostile elements to their own benefit. For shallow water exploration, artificial islands have already been widely used as drilling platforms. Now the drive is on to build bigger islands to support drilling and production in deeper waters. Dome Petroleum is already at work on the first; an island 600m across, in 60m of water, to support an entire operational community, complete with drill rigs, production and process equipment, and tanker loading facilities. The island is being built with dredged material but islands of the future, in deeper water can only be built if current dredging technology is advanced accordingly. A Dutch company is already working on a suitable dredger design. Transport to market of recovered reserves will depend on new breeds of vessels, too — ice-breaking tankers and LNG carriers.

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Canada: nature's riches from man-made islands

THE 1981 drilling season in the Beaufort Sea could be extremely significant for Dome Petroleum, which already has in Kopanoar, a structure comparable in size to BP's **Forties** field in the North Sea.

Discovered in September 1979, the field was tested last year and flowed 14 000bbl/d from the M13 location. A step-out well, started last year, is due to be completed this year and a further step-out is needed, says Dome, before further analysis can be made. The drilling is currently concentrated around the Eastern Lobe of the structure.

Because of the obvious environmental problems associated with drilling amid sea ice and also the shortness of the season, the operators have set themselves the target of 400 000bbl/d from each production facility on the field if it is to be economic. Despite these difficulties the company is confident that development will proceed with start-up being forecast for the mid-1980s.

Following the lead of Imperial Oil, Dome engineers are planning to produce from an artificial island. So far Imperial has constructed such islands in 20m of water, but the depths at Kopanoar are greater, being nearer 60m. Dome, however, believes that it can overcome this problem. Transportation to market would be by specially designed ice breaking tankers with a capacity of 200 000dwt.

Dome is also reporting that several other wells in the Beaufort Sea show promise. It plans five tests this season plus work that started last year and will be completed this year on two artificial islands to continue drilling around two of these structures. One island is near to Tarsiut A-25 which was drilled in 1979. Logging has indicated that there is a 160ft oil zone at a depth of 5 000ft and testing early in 1980 produced 800bbl/d on a restricted choke. One of the two islands is being constructed 3½ miles from this discovery while the other is being placed near to Kaglulik P74, drilling of which will start next year.

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Norway: ice, vessels and structure studies

DIRECT Norwegian involvement in developing technical solutions for oil exploration or production in Arctic waters has so far been relatively modest, despite a brief flurry of interest from some fabricators in the mid-1970s.

Activity in this field is currently limited to preliminary work on an innovatory 'ice-rig' concept for use initially on Canada's North Slope and a research programme intended to furnish analytical models and experimental techniques for computing ice loads on Arctic offshore structures.

Factors that account for this relative lack of interest include the priority understandably being given to the substantial research and development tasks facing Norway in the North Sea and on its big sub-Arctic shelf area between the 62nd and 71st parallels — where drilling has only just begun, of course.

Noting this, Norwegian scientists point out that much of the work currently being done on structural design, corrosion resistance, deep water drilling and so forth for these areas will to a large extent also be applicable later to regions even further north.

'In principle, Arctic waters involve the same environmental influences as the rest of the Norwegian sector, but to a stronger degree,' says Professor Gjørve at the Norwegian Institute of Technology (NTH) in Trondheim. 'We will be able to use existing expertise on steel corrosion and durability of concrete in the sea there,' he adds.

Another disincentive has been the sensitive legal status of the far northern continental shelf area in the Barents Sea, which extends 600 miles or so from the North Cape past Norway's Svalbard archipelago.

Complex jurisdictional disputes in these waters between Norway, the Soviet Union and the USA — which hinge on the unusual limitations to Norwegian sovereignty in Svalbard and disagreements about boundary lines with the Russians — means that the Norwegian authorities have adopted a very low profile there.

Pointing out that significant ice problems are not encountered on the Norwegian shelf until the Barents Sea is reached, Kaare Gisvold, now head of Trondheim's Nordex offshore engineering and fabrication firm, has argued for a more active approach to Arctic technology.

'A far-sighted Norwegian continental shelf policy should also evaluate the possibility that it may be necessary to start activities on the Svalbard shelf earlier than one would otherwise like,' he warned in a speech at the end of 1979.

American firms have collected substantial seismic data from this region, and Finland is supplying the Soviet Union with drillships that could be used there, he noted. 'This ought to suggest a substantial technical awareness of technology for Arctic petroleum production, something which has still not been recognised by the Norwegian authorities.' Matters have not improved any up to the present, Gisvold confirmed recently.

The Eastern side of Svalbard has been selected as the assumed site of an offshore oilfield development for a project to dimension a possible offshore production platform and transport tanker that could operate in such waters, however.

The study forms part of the so-called MSSI (Marine Structures and Ships in Ice) programme that was launched in 1978 and is due to end this year.

Groundwork

Backed by several Norwegian companies and research agencies, the scheme is aimed more at laying the groundwork for future Arctic offshore platform or vessel designs than producing actual detailed solutions. Apart from devising computational methods and experimental techniques to forecast ice loads, it has also sought to obtain data about ice characteristics and environmental conditions in such areas.

The theoretical studies have accordingly drawn heavily on surveys of existing literature, although further work has been done in areas where information was lacking.

The material collected through 16 sub-projects — covering such topics as mechanical properties of ice, ice loads on marine structures, ice modelling techniques, model testing with artificial ice, icing, mooring and loading systems, global/local loads on offshore structures due to ridges and structural vibration in ice as well as the Svalbard design case — is still being treated by and large as confidential. Publication of some or all of the results may occur by the end of the year, the project organisers say.

A seminar to present the MSSI project's results is planned for some time in 1981, although no specific date has yet been given.

Much attention in the programme is paid to developing satisfactory methods for conducting model trials or theoretical calculations to establish ice loads on offshore structures.

This work has included systematic testing of a standardised ice breaker model of an existing vessel — thus allowing comparison with results from full-scale trials — as part of a co-operative programme under the International Towing Tank Conference (ITTC) that also involved institutions in Finland, the Soviet Union, the USA and West Germany.

The conclusion so far has been that model trials, though expensive and time-consuming, seem to be the most reliable way of estimating ice-loads.

More work on comparing analytical ice load models with model test results and full-scale measurements is required before the former can cope with more than very simple ice-structure interactions, however.

The design case for the supposed location off Svalbard covers such computations as determination of relevant mechanical properties and failure strength of ice in the area, evaluation of form design of the structure, calculation of ship resistance in ice for determination of necessary powering and calculation of design ice loads for the main strength members of the platform.

Intended to be completed by this autumn, the exercise is meant to illustrate the use of the methods and data provided through MSSI.

Although fabricators such as Aker, Trosvik and Norwegian Contractors produced designs for Arctic rigs, platforms and tankers during the enthusiastic years of the mid-1970s, when an early extension of exploration into far northern waters was expected on a large scale, little appears to be being done in this field today.

But work is currently under way with a preliminary study of the idea for a floating offshore drilling or production unit made from artificial ice.

Conceived by an Oslo lawyer named Eystein Husebye, the scheme is now being developed further in collaboration with Norway's Aker Engineering company and Stal-Refrigeration AB of Sweden. Initial funding of NKr400 000 is being provided by the Nordic Investment Bank, and results from the relatively comprehensive study planned should be ready by the summer.

According to Husebye, who holds the rights to the concept, it has been greeted with interest in Canada and Alaska as an alternative to dredge-filled islands on the North Slope — not least because it could offer a cheaper solution for deeper water.

Due to be presented at the Canadian Offshore Resources exhibition in Halifax from June 22-24, the idea involves building a thin circular steel rim inside which the ice would be created artificially but maintained by the low ambient temperature. Buildings and equipment could be contained within the ice. □

How geotechnical engineers conquered the Beaufort Sea

IN THE Beaufort Sea, to the north of Canada and Alaska, a vast oilfield is being steadily developed in the face of conditions which, until recently, were considered too hostile for exploratory work.

Ice floes, extreme cold and frozen soil make the gathering of geotechnical data very difficult. However consulting engineers and geologists of Fugro Gulf Inc of Houston, Texas, with colleagues from Fugro BV, of Leidschendam, Holland, have succeeded in carrying out the most extensive programme of its kind in the area, despite severe climatic restraints.

Working for Dome Petroleum Ltd, Fugro Gulf — project manager, Larry S Marr — was responsible for overall project management and supervision of all drilling and sampling operations, and field soil testing. It provided and operated its Wison cone penetrometer test (CPT) equipment and C-Floor 9 equipment.

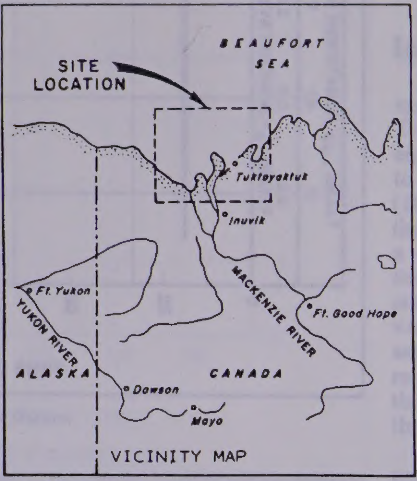
CPT soundings and soil samples were obtained at six possible offshore structure locations, and numerous other locations were investigated as possible sources of borrow materials for construction of artificial islands.

Field and laboratory soil testing was conducted by EBA Engineering Consultants Ltd; geophysical logging of boreholes was by Roke Ltd; the survey vessel was supplied by Canadian Marine Drilling Ltd (CANMAR); navigation and positioning was by Offshore Navigation Ltd.

Drilling and sampling

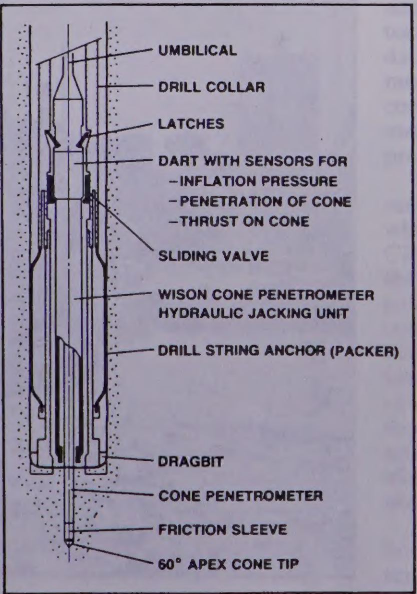
The field investigation consisted of drilling and sampling to recover soil samples, and in-situ testing. A conventional rotary drilling rig (Failing 1500) provided by CANMAR was used to drill the borings through an open well, fabricated through the deck and hull of the MV *Canmar Supplier V*.

The drill rig was positioned on a platform some 12ft (3.7m) above the deck of the vessel to allow sufficient height of the derrick for handling the in-situ testing tools. CANMAR provided 4½in. (114mm) OD IF drill pipe, drilling subs, core barrels, and open-ended drill bits. Fugro provided a heave compensator, appropriate drilling subs, and drill bits to enable using the push sampling and in-situ CPT tools. The heave compensator was used to control the vertical motion of the drill string during push sampling and in-situ testing operations.



Site location in Beaufort Sea

Samples were taken continuously to a depth of 40ft (12.2m) and at 10ft (3m) intervals thereafter. Cohesive soils were sampled with 2½in. (63.5mm) OD thin-walled tube samplers, 3ft (1m) long, and 2½in. (63.5mm) OD, 2⅛in. (54mm) ID liner samplers, 2ft (0.6m) long. The liner sampler was used for shallow soft soils.



Cross section of the Wilson CPT equipment

The samplers were driven with a 185lb (84kg) sliding hammer fabricated in the head of the sampling apparatus. The unit was lowered through the drill string and operated with a wire line. The hammer was raised with the wire line and dropped approximately 5ft a sufficient number of times to obtain 18 to 24in. (0.5m to 0.6m) of sampler penetration or until driving resistance became excessive.

The actual length of each sample was measured after retrieval of the sampler, and this value was used to compute the average number of blows per foot of penetration required to advance the sampler at that depth. Samples of both unfrozen and frozen soils were taken in this manner.

The Fugro 'Wip' push sampler was also used to retrieve a few soil samples. The Wip sampler, an hydraulically operated downhole tool, pushes a 3ft (1m) long thin walled tube, with or without a plastic liner, into the soil at a constant rate of penetration of about 0.8in./sec (2cm/sec). The tool with sample was then retrieved, and the sample extruded and measured.

A Reese core barrel assembly provided by CANMAR was used to retrieve samples of frozen soils. This wire line operated inner core barrel was lowered into the drill string, latched into place, and rotated into the soil with the drill string. The maximum diameter of the core obtained was 2⅜in. (60mm). The actual diameter of the core was less, due to thawing of the soil during coring and handling. Cores of 5ft and 10ft (1.5m and 3m) length were recovered using this equipment. The cores were then stored in a freezer onboard the MV *Canmar Supplier V*.

Cores and samples were extruded from the core barrel or sampler, examined, and visually classified by the Fugro geotechnical engineer and EBA soils technician onboard the vessel. Soil shear strength, unit weight, and water content tests were performed onboard the MV *Canmar Supplier V* during drilling and sampling operations. Temperatures of most samples were measured, and selected samples were photographed. Other selected samples were specially packaged for gas content

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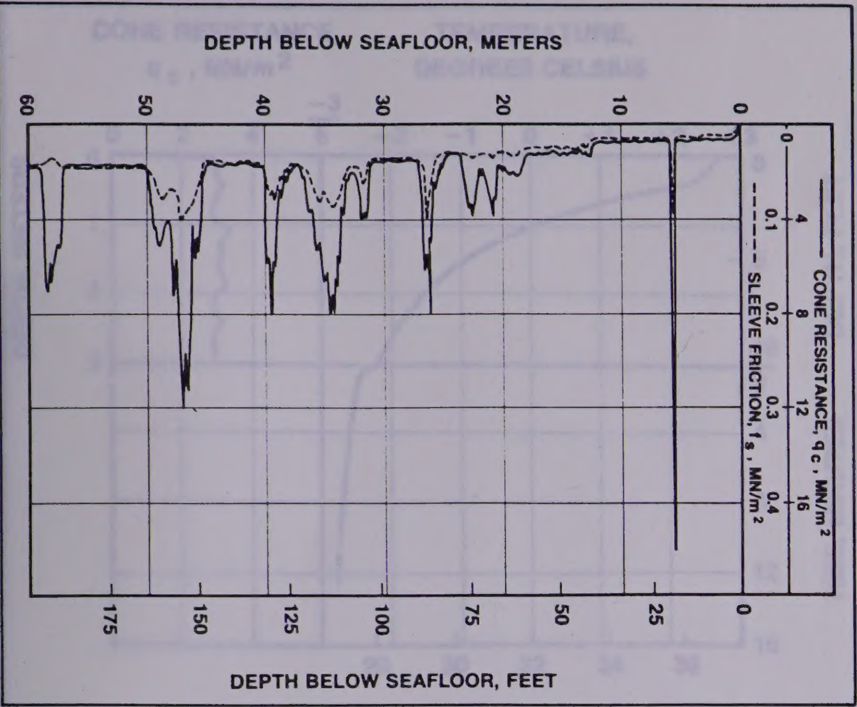

Cone penetrometer readings of cone tip resistance and sleeve friction

Ice strewn water at Tuktoyaktuk — the resupply and refuel base

◀ *FROM PAGE 21*

testing; these gas content samples were sent to Carbon Systems Inc, Baton Rouge, Louisiana. Portions of all soil samples were sealed in moisture-tight containers, labelled, and stored for transportation to EBA soils laboratory. Frozen soils were stored in a freezer onboard the MV *Canmar Supplier V* after sampling. They were then shipped in special core boxes to EBA soils laboratory for testing.

In-situ testing

Cone penetration tests (CPTs) were made using Fugro Wison equipment. This hydraulically-operated downhole equipment measures the thrust required to push a 60° apex cone of $1.55in^2$ ($10cm^2$) base area into the ground, and the frictional resistance to penetration of a cylindrical sleeve immediately above the cone. The rate of penetration is constant at 0.8in./sec (2cm/sec) and cone values are measured and recorded automatically on a dual strip chart recorder. The Wison uses the weight of the drill string as a reaction force to push the cone into the soil.

A drill string anchor (packer) was used in some cases to increase the reaction force, allowing additional cone penetration into hard or dense soils up to maximum capacity of the cone. A heave compensator was used to control the vertical motion of the drill string during the Wison CPT sounding operations. Cone tip resistance, q_c, is represented by a solid line and sleeve friction, f_s, is represented by a dashed line on the CPT soundings.

A specially designed temperature sensitive cone was periodically used during the field investigation. This cone replaced the normal cone penetrometer and allowed measurement of in-situ temperature and cone tip resistance, q_c, data. Sleeve friction resistance was not measured while using the temperature cone. Results of in-situ temperature measurements were included in the data produced.

The C-Floor 9 is a remotely operated, seabed supported, in-situ testing unit which performs both field vane test and CPT soundings. The unit is lowered to the seafloor, and a chain-driven device pushes an 11.5ft (3.5m) long rod with the cone into the soil at 0.8in./sec (2cm/sec). For field vane tests, the rod with the vane blades attached in place of the cone, is stopped at selected depths and then rotated at 1.5° per second until the soil fails. The reaction force available to allow soil penetration of the probe was provided by the weight of the C-Floor 9.

Field soil test results, visual descriptions, Wison cone penetrometer test results, and C-Floor 9 test results were

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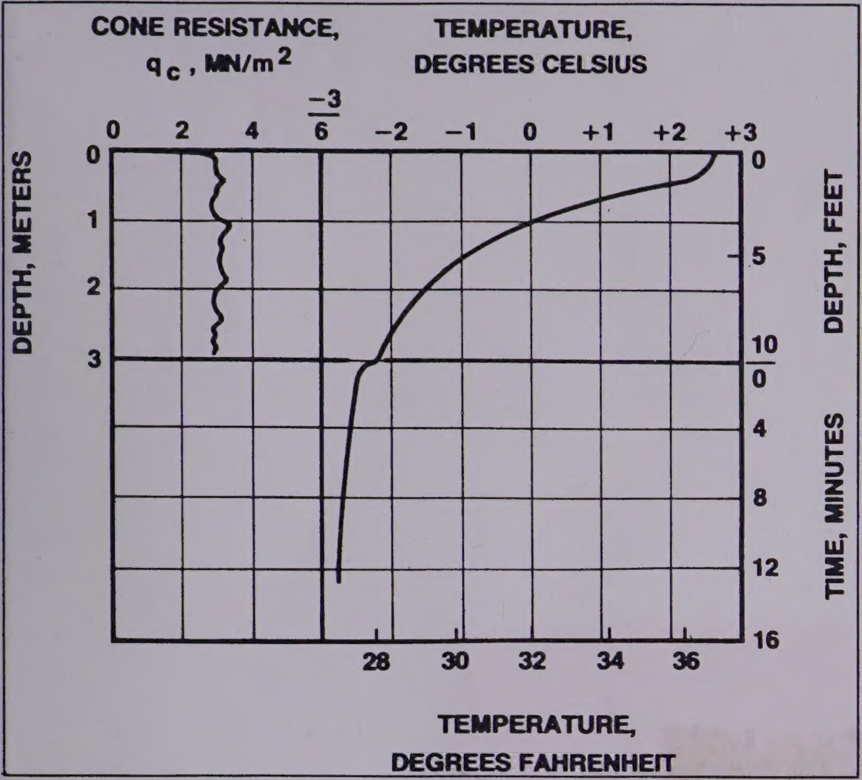

Recording of temperature sensitive cone test

◀ *FROM PAGE 22*

evaluated to determine soil conditions at each site. Logs of the borings and CPT results were presented as appendices. Wison cone penetrometer test (CPT) results were presented as curves of cone resistance q_c and sleeve friction f_s, versus depth below seafloor. Interpretation of this data provides estimates of soil type and cohesive soil shear strength of granular soil density. Shear strength and density data from CPT results were combined with field and laboratory soil test results to obtain the best estimate of soil conditions. In cohesive soils, estimates of in-situ undrained shear strength were obtained from cone resistance, q_c, (adjusted for total overburden pressure) divided by a bearing capacity factor, N_k, ranging between 10 and 15⁽²⁾.

In granular soil, estimates of in-situ relative density were made from Wison data using a correlation of q_c, relative density, and vertical effective stress presented by Schmertmann.*

During the latter part of the programme freezing temperatures caused many problems and slowed the drilling operation. The primary difficulty was keeping the mud system operating. Mud hoses had to be drained after each borehole and, in one instance, the rig mud pump stopped pumping due to ice formation in the valves. Ice formed quickly in the mud mixing tank and had to be removed on occasion.

Another problem was ice in the centre well. On several occasions this ice plug jammed the drill pipe against the side of the centre well so that the slips could not be inserted. Frozen anchor winch controls was another source of delay during anchoring.

Hot water from the vessel's fresh water tanks was effective for thawing ice in both the mud system and the centre well; however, this seriously depleted the vessel's fresh water supply. Propane torches were effective both for thawing anchor winch controls and for removing moisture from the mud pumps after draining. Salt and sawdust helped to keep the working areas safe.

There were other problems caused by cold weather. In late summer, when the ice started to move, small icebergs (some the size of the survey vessel) tended to get fouled in the anchor cables, and the crew had to manoeuvre around them. Equipment froze and had to be thawed by torch every few days. Frozen samples had to be obtained using a rock core barrel, making it impossible to obtain undisturbed samples, and extreme cold slowed down the crew. □

Members of the Fugro drilling crew on Beaufort Sea site

Arctic data from pup-joints

HYDRIL CO's Advanced Ocean Systems Division has developed a subsea instrumentation system to monitor the Arctic regions, according to Dr M Davis, Hydril AOS manager of research and development.

Designed for Dome Petroleum Ltd of Canada, the system's most important features are instrumented pup-joints that gather data on pressure, temperature and casing stress. Davis added that the 'system will acquire data automatically and store it for periodic logging through a central computer.'

Hydril AOS will instrument each pup-joint. A dedicated DAC will process and multiplex raw data for transmission to the surface. Hydril's Flatpak umbilical will communicate data from the pup-joints to the surface. The umbilical features a rugged, flat configuration designed for the installation. □

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* (Schmertmann, John H, (1977), *Guidelines for Cone Penetration Test Performance and Design*, US Department of Transportation, FHWA-75-78-209).

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